KIE2002-LAB 4 SEM 4 2026/2027

EXPERIMENT CM8: ANALOG MODULATION USING MATLAB

Related course: KIE2008 (Communication System)

OBJECTIVES:
1. To generate AM, DSB-SC AM, PM, and FM waveforms using MATLAB
2. To observe and analyze the modulated waveforms in both time and frequency domains

EQUIPMENT:
PC with MATLAB 2017a/b and after

INSTRUCTIONS:
1. Follow the procedure in this lab sheet
2. Copy all results into a Word document
3. Every student must submit the experiment results (in Word) and the simulation files (in MATLAB) to the lab course Spectrum before end of the experiment week

REFERENCES:
John G. Proakis, Masoud Salehi, "Fundamental of Communication Systems", 2nd Ed., Prentice Hall, 2014

INTRODUCTION:

Consider a carrier $c(t) = \cos(2\pi f_c t)$ and the message signal $m(t)$ that may take various waveforms, the modulated signal can be represented as $u(t)$. In analog communication, there are three modulation techniques: amplitude modulation (AM), phase modulation (PM), and frequency modulation (FM). In this experiment, we are going to apply four modulation schemes (AM, DSB-AM, FM and PM) on four types of signal (namely m_1, m_2, m_3 and m_4) to observe the output.

The general equation for these modulation schemes are given as:

$u(t) = A_c[1 + k_a m(t)]\cos(2\pi f_c t)$ (AM)

$u(t) = A_c k_a m(t)\cos(2\pi f_c t)$ (DSB-AM)

$u(t) = A_c m(t)\cos(2\pi f_c t + \phi(t)); \phi(t) = k_p m(t)$ (PM)

$u(t) = A_c m(t)\cos(2\pi f_c t + \phi(t)); \phi(t) = 2\pi k_f \int_{-\infty}^{t} m(\tau)d\tau$ (FM)

PROCEDURE:

1. Open a MATLAB script and type the MATLAB code given in the next page.
2. Examine and then run the file; observe that by selecting the message signal **mt** and the modulated signal **ut**, you are able to see different modulation types: AM, DSB-SC AM, PM, and FM, for the four types of signal. (A total of 16 sets of message-modulated pairs)
   (Q1) What are the four types of waveform being used?
3. Generate these waveforms one by one and record the MATLAB plots.
   (Q2) Confirm that they are the theoretically expected waveforms, by writing in your lab report the mathematical expression for each one.
   (Q3) Explain the code used for every modulation scheme.
4. Repeat the experiment by varying the values of the modulation constants (k_p, k_f and k_a). [hint: use values that you think are suitable]
   (Q4) What do you observe?

5. Given the following message signal, write code to perform the modulations and record the output. $u(t) = \begin{cases} t; 0 \le t < 1 \\ -t + 2; 1 \le t \le 2 \\ 0; otherwise \end{cases}$
6. Change fs = 2e3; to fs = 3e3; and repeat the whole experiment. Explain the difference from the previous findings when fs is changed.
7. Include in your lab report, the general comments and a description of what you have learned from this experiment.

MATLAB CODE:

```
% Experiment CM8 (Prepared by Assoc. Prof. Ir. Dr. Chow Chee Onn)
clear all; close all

% Parameter Settings
fs = 2e3; t0 = 0; tN = 4; t = t0:tN/fs:tN-1/fs;
Am = 1.0; Ac = 1.0;
fc = 10; fm = 1;
kp = 45; kf= 100; ka = 1.5;    % modulation index
a = 0.25;
T = t(end); t1 = numel(t)/2;   % Adjust time scale of 4 seconds

% Carrier
ct = Ac*cos(2*pi*fc*t);

% Message signals
m1 = a*cos(2*pi*fm*t);
m2 = [Am*ones(1,t1) -Am*ones(1,t1)];
m3 = [Am*t(1:t1) -6*Am*(t(t1+1:end)-T)/(T-t(t1))];
m4 = [Am*t(1:t1).^2/2 2+Am*(-t(t1+1:end).^2+2*T*t(t1+1:end)+t(t1)^2-2*T*t(t1))/(T-t(t1))];

% AM
AM_m1 = Ac*(1 + ka*m1).*cos(2*pi*fc*t);
AM_m2 = Ac*(1 + ka*m2).*cos(2*pi*fc*t);
AM_m3 = Ac*(1 + ka*m3).*cos(2*pi*fc*t);
AM_m4 = Ac*(1 + ka*m4).*cos(2*pi*fc*t);

% DSB-AM
DSB_m1 = Ac*ka*m1.*cos(2*pi*fc*t);
DSB_m2 = Ac*ka*m2.*cos(2*pi*fc*t);
DSB_m3 = Ac*ka*m3.*cos(2*pi*fc*t);
DSB_m4 = Ac*ka*m4.*cos(2*pi*fc*t);
```

```
% PM
PM_m1 = Ac*cos(2*pi*fc*t + kp*m1);
PM_m2 = Ac*cos(2*pi*fc*t + kp*m2);
PM_m3 = Ac*cos(2*pi*fc*t + kp*m3);
PM_m4 = Ac*cos(2*pi*fc*t + kp*m4);

% FM
FM_m1 = Ac*cos(2*pi*fc*t + kf/fm*a*sin(2*pi*fm*t));
FM_m2 = Ac*cos(2*pi*fc*t + kf*m3);
FM_m3 = Ac*cos(2*pi*fc*t + kf*m4);
FM_m4 = Ac*cos(2*pi*(fc + kf*m4).*t);

% Select a message signal and modulated signal to download and plot
mt = m1;
ut = FM_m1;
mt = mt / max(abs(mt)); ut = ut / max(abs(ut));        % Normalization

% Plot the waveforms
subplot(2,1,1); plot(t,mt,'LineWidth',4,'Color','Red')
ylabel('Amplitude','FontSize',12,'FontWeight','bold'); title('Message signal','FontSize',12,'FontWeight','bold')
axis ([-(max(t)-min(t))*0.0 max(t)*1.0 min(mt)*1.1 max(mt)*1.1]);set(gca,'FontSize',16);

subplot(2,1,2);plot(t,ut)
ylabel('Amplitude','FontSize',12,'FontWeight','bold')
title('... Modulation of the message signal','FontSize',12,'FontWeight','bold')
set(gcf,'Color',[1 1 1]);set(gca,'FontSize',16);
```

END OF EXPERIMENT